

Article

Environmental Regulations, Green Technological Innovation, and Green Economy: Evidence from China

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Abstract: With the advancement of the green economy, the influence of the environmental regulations on green technological innovation and the green economy is increasingly expanding. This paper investigates the impact of the environmental regulations and corporate green technological innovation on the green economy. We hope to explore how the environmental regulations affect the green economy through corporate green innovation. Thus, the research aims to enhance our understanding of the impact of the environmental regulations on the green economy. By incorporating the fixed-effects models, mediation models, spatial models, and regression analysis, this paper unveils the impact process of the environmental regulations on the green economy. The research findings are as follows: (1) The environmental regulations show the direct capacity to facilitate the elevation of the green economy. (2) Through the mediating variable of corporate green technological innovation, the environmental regulations could indirectly enhance the green economy. (3) Significant spatial correlations exist between the environmental regulations and corporate green technological innovation activities across the different regions in China. (4) Substantial disparities are evident in the relationships among the environmental regulations, green technological innovation, and the green economy across the various regions in China. The findings presented in this paper serve to broaden the scope of research on the relationship between the environmental regulations and the green economy. Moreover, it offers essential insights for the relevant government authorities and businesses in formulating management policies.

Keywords: environmental regulations; green technology innovation; green economy; threshold effect



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1. Introduction

Based on data from the United Nations Environment Programme, global greenhouse gas emissions have surged by approximately 50% since the advent of industrialization [1]. Carbon dioxide emerges as the predominant emission in this scenario. These emissions have precipitated a global temperature escalation, consequently instigating extreme weather phenomena. They have also engendered severe repercussions on agriculture, water resources, and ecosystems. Simultaneously, air pollution has emerged as one of the paramount environmental concerns on a global scale. According to data from the World Health Organization, around 7 million individuals perish annually due to diseases associated with air pollution. Particularly in developing nations and urban areas, the mortality rates are notably high. Additionally, water scarcity poses a significant threat to global sustainable development. As per data released by the United Nations, approximately 20% of the global population resides in regions afflicted by water scarcity. It poses significant challenges to people's access to drinking water, agricultural practices, and industrial productivity. Over

the past few decades, environmental issues on a global scale have increasingly come to the fore. Challenges such as climate change, air pollution, and water scarcity are exerting profound impacts on human society and ecosystems [2]. In the face of these environmental challenges, the international community universally acknowledges the imperative to take action to safeguard and enhance the environment. It fulfills the objectives of sustainable development. Hence, the environmental regulations, green technological innovation, and the transition to the green economy stand as pivotal means to achieve the environmental conservation goals.

The environmental regulations, green technological innovation, and the green economy each possess distinctive characteristics as follows: (1) The environmental regulations involve the management and conservation of the environment through legal, policy, and standard measures. Their aim is to restrict and reduce environmental pollution, resource wastage, and ecological degradation. Furthermore, the environmental regulations could stimulate businesses and individuals to adopt environmentally friendly practices. The implementation of the environmental regulations necessitates concerted efforts from government, businesses, and the public. It spans across various sectors and levels, including environmental protection, energy utilization, and waste management. Through the environmental regulation, a scientific and rational environmental management system could be established. It could enhance the effectiveness and standards of environmental protection [3]. (2) Green technological innovation embodies a trajectory of technological ingenuity guided by environmental benevolence and sustainable progress. Through the articulation and deployment of eco-friendly technologies and solutions, it enhances the efficiency of resource employment while curtailing environmental contamination and ecological degradation. Concurrently, green technological innovation embraces a spectrum of domains including renewable energy, clean production methodologies, and circular economy practices. The proliferation and invocation of green technological innovation could propel a greening of the economy. It also ushers in a virtuous cycle of economic prosperity intertwined with environmental safeguarding. Nonetheless, the maturation of green technological innovation encounters challenges on fronts such as technological expenditures, market exigencies, and policy bolstering [4]. (3) The green economy denotes an economic model founded on environmental sustainability and resource efficiency, fostering economic growth. It accentuates the utilization of innovative, environmentally friendly technologies and the products to diminish resource consumption and environmental pollution. Consequently, it could drive sustainable economic growth. The progression of the green economy could extend economic support and societal underpinnings for the enforcement of environmental regulations. Simultaneously, it could generate market demand and commercial prospects for green technological innovation. The emergence of the green economy offers nations a dual-win proposition, enabling the pursuit of economic expansion while safeguarding the environment [5]. To sum up, in this context, the synergistic development of the environmental regulations, green technological innovation, and the green economy emerges as being particularly pivotal. The environmental regulations could propel the advancement of green technological innovation. By constraining and guiding corporate conduct, the environmental regulations could simulate enterprises to adopt eco-friendly technologies and sustainable operating models. Concurrently, both the environmental regulations and green technological innovation could stimulate the growth of the green economy from diverse perspectives. Thus, it is evident that there exists a notably intricate interplay among the environmental regulations, green technological innovation, and the green economy.

The aims of this paper are as follows: (1) We aspire to investigate the impact process of the environmental regulations on the green economy. Initially, we would delineate the current status of the environmental regulations and the development of the green economy in China. Subsequently, we would delve further into the specific influence process of the environmental regulations on green technological innovation. (2) We aim to investigate the mediating role of green technological innovation in the impact process of the

environmental regulations on green technological innovation. During the process where the environmental regulations influence the green economy, we have observed that green technological innovation plays a significant role. Through this paper, we hope to distinctly elucidate the specific contributions of green technological innovation in this process. (3) We aim to unveil the varying impacts of the environmental regulations on the green economy across different regions. Given the vast geographical expanse of China, the environmental regulations and the green economy differ across various regions. In this way, we seek to uncover the influence of the environmental regulations on the green economy in different regions of China.

The research significance of this paper is as follows: (1) We enrich the research landscape concerning the environmental regulations and the green economy. Previously, scholars have seldom integrated green technological innovation with the environmental regulations and the green economy in their studies. Building upon existing research, this paper further enriches the discourse on the environmental regulations and the green economy. (2) We have extended the application scenarios of relevant empirical research methods. We employ methods such as the threshold effect test and the heterogeneity test to examine the relationship between the environmental regulations and the green economy. The paper ventures into uncharted territory. Scholars have seldom utilized such methodologies in investigating this issue. Thus, our research further broadens the application scenarios of these empirical research methods. (3) The conclusions of this paper offer vital insights for the pertinent businesses and governmental decision-making. Our research findings serve as crucial reference points for relevant businesses in formulating strategies for managing green technological innovations and for governments in crafting supportive policies.

The subsequent arrangements for this paper are as follows: (1) Literature Review. This section primarily synthesizes the research literature on the interplay among the environmental regulations, green technological innovation, and the green economy. (2) Theoretical model and hypotheses. This section focuses on constructing the theoretical model of this paper, along with outlining three pertinent research hypotheses. (3) Research design. This part encompasses variables, empirical model establishment, data, variable reliability, and validity testing. (4) Results. This segment includes the threshold test, robustness testing, further analysis, endogeneity tests, and the heterogeneity tests. (5) Conclusions, implications, and the research limitations. This section comprises the overarching research conclusions, the practical implications, the research limitations, and the future research directions.

2. Literature Review

2.1. *The Relationship between the Environmental Regulations and the Green Economy*

Firstly, the environmental regulations are the catalyst for the development of the green economy. The environmental regulations could restrain environmental pollution and waste of resources and promote the green economy. At the same time, the environmental regulations could also achieve this transition by limiting emissions and reducing waste generation [6]. In addition, these regulations could also promote the development of the green economy by limiting carbon emissions in the energy sector. On the contrary, the green economy also provides important support for the implementation of the environmental regulations. The green economy could reduce resource consumption and environmental degradation. The green economy also provides important technical support for the implementation of environmental regulations. Moreover, the green economy could drive companies to deploy more advanced environmental monitoring, pollution control, and resource recovery technologies. It would improve the effectiveness of the environmental regulations [7].

Furthermore, there exists a mutually reinforcing and synergistic relationship between the environmental regulations and the green economy. The strengthening of the environmental regulations and the green economy bolster each other, creating a symbiotic cycle. The demands of the environmental regulations drive the growth of the green economy and market needs. However, the development of the green economy also provides impetus and conditions for the enhancement and escalation of environmental regulations [8]. Further-

more, the requirements of the environmental regulations concerning pollutant emissions and waste management are becoming more strict. As a result, a variety of environmental conservation and clean energy technologies have surfaced within the domain of the green economy. This influx supports the achievement of sustainable development objectives.

In conclusion, the synergistic development of the environmental regulations and the green economy holds significant importance for achieving sustainable development goals. Strengthening the environmental regulations and fostering green economic growth could facilitate a green transformation of the economy. It establishes a virtuous cycle of economic growth and environmental protection. Moreover, the green economic model encompasses enhanced environmental regulations, constraints on environmental pollution and resource wastage. In addition, it encourages businesses to adopt green technologies and sustainable practices. These operational models could propel the economy towards a direction characterized by low-carbon emissions, cleanliness, and circularity. Simultaneously, the green economy also provides economic support and a social foundation for the environmental regulations. It also facilitates the realization of sustainable development goals.

2.2. The Relationship between the Environmental Regulations and Green Technology Innovation

Initially, the environmental regulations could drive the development of green technological innovation. The enforcement of the environmental regulations typically imposes higher environmental protection requirements and standards on businesses and industries. The pressure propels businesses and industries to innovate in green technology, seeking greener and more sustainable solutions [9]. Specifically, the environmental regulations on pollutant emission limits prompt companies to develop more efficient pollution control technologies. Furthermore, the environmental regulations could stimulate the companies to adopt low-carbon and clean energy technologies. This is achieved through economic tools such as emission permits and carbon trading. These measures foster innovation and the implementation of green technologies.

Secondly, green technological innovation supports the implementation and enforcement of the environmental regulations. It provides advanced and efficient environmental protection technologies, offering technical assistance for regulatory enforcement. Novel environmental monitoring, pollution control, and resource recovery technologies aid regulatory agencies in more accurately monitoring and assessing environmental conditions. Thus, it enhances the effectiveness of the regulatory enforcement. This technology could improve the efficacy of the environmental regulations [10]. Furthermore, green technological innovation could reduce environmental protection costs and enhance corporate compliance with the environmental regulations. Through innovative eco-friendly technologies, businesses could lower resource consumption, decrease energy usage, and cut waste emissions. These technologies could also mitigate the risks of environmental pollution and ecological damage, aligning with the environmental regulatory standards [11].

Lastly, there exists a mutually reinforcing relationship between the environmental regulations and green technological innovation. The implementation of the environmental regulations relies on the support and application of green technologies. However, the innovation and application of green technologies also require the guidance and impetus of the environmental regulations. These two aspects interact, forming a virtuous cycle. The demands of the environmental regulations drive the innovation of green technologies and market demand [12]. Simultaneously, the innovation of green technologies provides a technical foundation and support for the advancement of the environmental regulations. For instance, as the environmental regulations become increasingly stringent on carbon emissions, a range of low-carbon and clean energy technologies have emerged in the field of green technology. These green technologies offer vital support for achieving a low-carbon economy and sustainable development.

In conclusion, the synergistic development of the environmental regulations and green technological innovation holds significant importance. Enhancing the environmental regulations could drive the green economy shift. It fosters efficient resource usage and

sustainable environmental growth. The environmental regulations could foster economic progress and environmental preservation by curbing pollution, minimizing resource waste, and promoting green technologies and sustainable business models. Additionally, there exists a close interactive relationship between the environmental regulations and green technology innovation. They support and bolster each other, catalyzing mutual advancement and harmonized growth. Thus, they play pivotal roles in achieving environmental protection and sustainable development goals. Moving forward, relevant stakeholders should continue to enhance coordination and cooperation between the environmental regulations and green technology innovation. It fosters the development of the green economy and establishes a sustainable society and environment.

2.3. The Relationship between Green Technology Innovation and the Green Economy

Firstly, green technological innovation plays a pivotal role in driving the development of the green economy. By developing and implementing environmentally friendly technologies and solutions, it enhances resource efficiency. It also reduces pollution and ecological degradation to support the realization of a green economy. Innovation in green technologies spans various sectors, including renewable energy, clean production techniques, and circular economy technologies. The application of these technologies could lessen dependence on traditional energy sources, driving the transformation of the energy structure. Moreover, it could promote the development of a low-carbon economy [13]. The rapid growth of renewable energy sources such as solar and wind power provides sustainable energy supply for the green economy, reducing reliance on fossil fuels. In addition, it also decreases carbon emissions and air pollution.

Secondly, the development of the green economy provides market demand and business opportunities for green technological innovation. The green economy model emphasizes the efficient use of resources and sustainable environmental practices. By innovating and applying environmentally friendly technologies, the green economy reduces environmental pollution. Moreover, the green economy creates market demand and business opportunities for green technological innovation. It motivates enterprises to engage in technological innovation and product development [14]. Specifically, with the rise of the green economy, green technological innovation is rapidly advancing in areas such as clean energy, energy efficiency, and environmental protection. It also manages wastes, leading to the emergence of competitive green technologies and products.

Lastly, there exists a mutually reinforcing and synergistic relationship between green technological innovation and the green economy. Green technological innovation provides technical support and innovation impetus for the development of the green economy. At the same time, the advancement of the green economy creates market demand and business opportunities for green technological innovation. The interplay between the two forms a virtuous cycle. The impetus from green technological innovation drives the growth of the green economy and expands the market. In addition, the development of the green economy provides investment and resource support for green technological innovation. Furthermore, the demand from the green economy accelerates green technological innovation. Green technological innovation, in turn, offers the green economy a broader range of technological choices and solutions [15].

In conclusion, the synergistic development of green technological innovation and the green economy holds significant importance. The application of green technological innovation could enhance resource efficiency and reduce environmental pollution and ecological degradation. In addition, it also establishes a virtuous cycle of economic growth and environmental protection. Furthermore, the development of the green economy provides market demand and business opportunities for green technological innovation. It fosters the commercialization and widespread adoption of green technologies. Through the coordinated development of green technological innovation and the green economy, it is possible to drive the green transformation of the socio-economic landscape. It depends on sustainable economic development and ecological improvement. Moreover, there exists

a close relationship between green technological innovation and the green economy. The two mutually promote and support each other, collectively propelling the coordinated development of economic growth and environmental protection. Moving forward, it is imperative to further strengthen the coordination between them to advance the development of the green economy. It also achieves sustainable economic development and environmental preservation.

2.4. Literature Gaps

This paper has synthesized relevant research literature. It has been observed that some scholars have embarked on research regarding the relationship among the environmental regulations, green technological innovation, and the green economy. Nonetheless, scholars' investigations carry certain inadequacies, manifested as follows: (1) There is a relative scarcity of research focusing on the relationship between the environmental regulations and the green economy in China. Most scholars have concentrated their studies on the environmental regulations or the green economy matters within specific local regions. Concerning the comprehensive relationship between the environmental regulations and the green economy in China, there has been a limited amount of scholarly exploration. (2) Studies on the environmental regulations have predominantly been theoretical in nature, lacking sufficient empirical analysis. Moreover, some of the literature features relatively small data samples, leading to research conclusions that lack adequate persuasiveness. (3) In exploring the impact of the environmental regulations on the green economy, few scholars have integrated corporate green technological innovation into their investigations. It results in a certain degree of one-sidedness in research on this issue. To effectively address the deficiencies in scholars' research endeavors, the authors have delineated the research title and content of this paper. Thus, this paper would enhance the relevant theoretical research content. At the same time, it would also furnish crucial insights to further the advancement of China's green economy.

3. Theoretical Model and Hypotheses

There exists a close interplay between the environmental regulations, green technological innovation, and the green economy. They mutually propel and coalesce to advance the realization of sustainable development. We hope to vividly elucidate the relationships among the environmental regulations, green technological innovation, and the green economy. Thus, we put forth the theoretical model and hypotheses delineating their interconnections.

The environmental regulations show diverse positive impacts on the green economy. Firstly, these regulations drive businesses to transform and upgrade, hastening the shift towards green production. Stringent environmental mandates require companies to reduce pollutant emissions, save energy, and enhance resource efficiency. It compels them to embrace eco-friendly, low-carbon production methods. Thus, it drives the progression of the green sectors and encourages the refinement of economic frameworks [16]. Subsequently, the environmental regulations stimulate companies to enhance their investment in environmental technology research and application. To meet the regulatory requirements, enterprises must amplify their efforts in green technology innovation. It also should explore and apply more high-efficiency technologies and products. Such technological advancements could enhance a company's competitive edge. It also steers the entire industry chain towards the green economy [17]. Furthermore, the environmental regulations offer market demand and development opportunities for green industry. With the rise in environmental awareness and strengthening of environmental laws, there is a continual increase in consumer demand for eco-friendly products and services. By adhering to the environmental regulations, companies could enhance their market recognition and support. They could also expand the green market space by producing green products and offering eco-friendly services. Ultimately, it could drive the development of the green economy [18]. The positive impact of the environmental regulations on the green economy is evident in various aspects. These include driving corporate transformation and upgrades. It promotes

technological innovation and creates market demand and development opportunities. This influence contributes to achieving a win-win situation for economic sustainability and environmental protection. It also provides crucial support and assurance for promoting the healthy development and transformation of the green economy. Based on the analysis provided above, this paper puts forward the following hypothesis:

Hypothesis 1 (H1). *The environmental regulations show a positive impact on the green economy.*

The impact of the environmental regulations on green technology innovation manifests in various ways and shows far-reaching implications. Firstly, the environmental regulations strengthen the demand for environmentally friendly technology research and development within companies. It also drives them to increase investments in green technological innovation [19]. Companies, in order to comply with the environmental regulations, are compelled to seek more eco-friendly and efficient solutions. Thus, it advances technological innovation continuously. Secondly, the environmental regulations stimulate research institutions and businesses to increase their investments in green technology innovation. Both businesses and research institutions need to improve existing technologies or develop new ones to innovate in areas. The pressure and demand prompt research institutions and businesses to escalate investments in green technology research and development. Moreover, it fosters the continuous emergence of green technologies [20]. In addition, the environmental regulations provide market demand and development opportunities for green technological innovation. With the increasing environmental awareness, the market demand for green technology continues to grow. Leveraging the market demand, companies increase their investments in green technological innovation. It drives the commercialization of green technologies, creating a positive feedback loop [21]. In general, the positive impact of the environmental regulations on green technology innovation is evident in stimulating companies. It also prompts research institutions to enhance technological innovation and provides development opportunities. This influence could drive the innovation of green technologies. It also makes a positive contribution to the sustainable development of environmental conservation efforts. Building upon the analysis above, this paper puts forth the following hypothesis:

Hypothesis 2 (H2). *The environmental regulations show a positive influence on green technological innovation.*

Green technological innovation shows a multifaceted positive impact on the green economy. Firstly, green technological innovation drives the development of the green industry. By continuously enhancing green technologies, companies could produce products that are more environmentally friendly. This, in turn, meets consumers' demand for eco-friendly products, thereby fostering the rise and advancement of the green industry [22]. Secondly, green technological innovation enhances the competitiveness and innovation capabilities of enterprises. Introducing green technologies could reduce production costs, improve efficiency, and also enhance corporate image. Thus, it garners more recognition and support from consumers. This innovation-driven development model not only helps companies stand out in market competition but also inspires a continuous drive for innovation. It also pushes the entire industry towards a green and sustainable direction [23]. Furthermore, green technological innovation promotes the efficient utilization and recycling of resources. Through the application of green technologies, companies could manage and utilize resources more effectively, reducing energy consumption. In addition, they also could reduce waste emissions, achieve resource circulation, and lessen environmental burdens. This circular economy model not only aids in reducing resource wastage but also fosters sustainable economic development [24]. In conclusion, the positive impact of green technological innovation on the green economy is mainly manifested in driving the development of the green industry. It also enhances enterprise innovation capabilities and promotes the efficient utilization and recycling of resources, among other aspects. Moreover,

this type of technological innovation contributes to achieving a win–win situation between economic growth and environmental protection. It also provides vital support and impetus for building a green, low-carbon, and sustainable economic development model. Based on the above analysis, this paper puts forward the following hypothesis:

Hypothesis 3 (H3). *Green technological innovation shows a positive impact on the green economy.*

Based on the aforementioned analysis, we have constructed the theoretical model for this paper (as depicted in Figure 1). There exist intricate interrelationships among the environmental regulations, green technological innovation, and the green economy. The environmental regulations could propel the development of the green economy. Simultaneously, advancements in the environmental regulations could also foster the enhancement of green technological innovation. However, as the level of green technological innovation improves, it could further drive the development of the green economy [25].

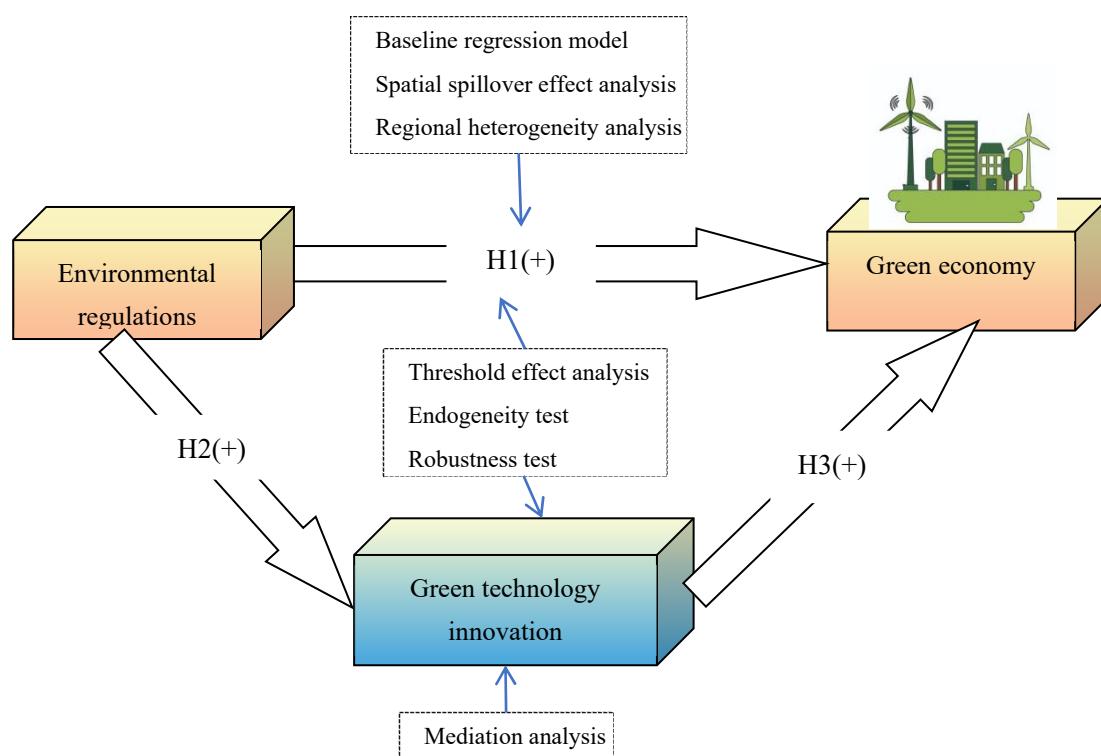


Figure 1. The conceptual framework of this paper.

As depicted in Figure 1, in order to further validate the theoretical model, we would integrate the relevant research data and employ empirical methods. We would use the baseline regression model, the spatial spillover effect, and the regional heterogeneity analysis. These methods are used to paper the process of the environmental regulations' impact on the green economy. At the same time, we also use the intermediary effect to analyze the intermediary role of green technology innovation. In addition, we would use the threshold effect analysis, endogeneity test, and robustness test. These empirical methods are used to test the theoretical model relationships proposed above. Then, we could derive more scientific and accurate research conclusions.

4. Research Design

4.1. Variables

(1) Explained variable

The dependent variable in this paper is the green economy (GE). The green economy is premised on the efficient utilization of resources and the protection of the ecological environment. It is achieved through technological innovation and optimizing the adjustment of traditional industrial structures to overcome existing constraints on environmental resources. Thus, it could realize the harmonious integration of the economic, resource, environmental, and social systems [26].

The reasons why we choose the specific indicators to measure the green economy are as follows: (1) We have primarily referenced the “Green Development Indicator System” jointly issued by the Chinese National Development and Reform Commission. (2) We refer to the indicators of the green economy division by relevant scholars in this field. Some scholars have divided the measurement indicators of the green economy from different angles. We have reviewed the relevant research findings. (3) We select relevant indicators for which data could be found. In the process of index determination, we eliminate the data index that is incomplete or that could not be found and leave the index that could be found completely.

Building upon the above reasons, this paper divides the green economy evaluation indicator system into 4 standard levels: economic growth, resource conservation, environmental protection, and socio-economic well-being. Additionally, we have established 20 secondary indicators to comprehensively assess the development of the green economy between 2004 and 2023. The specific contents of the green economy evaluation indicator system are outlined in Table 1.

- (a) Economic growth. Our primary selection includes per capita regional gross domestic product, economic density, the proportion of industrial output, the proportion of tertiary industry output, and R&D expenditure. Among these, per capita regional gross domestic product and economic density indicators are used to reflect the level and scale of urban economic development. The proportions of industrial output and tertiary industry output reflect the distribution of the economic development structure. R&D expenditure, on the other hand, mirrors the investment in technological innovation within the economic development.
- (b) Resource conservation. We encompass indicators such as energy consumption per unit of the regional gross domestic product, electricity consumption per unit of regional gross domestic product, water conservation, and the comprehensive utilization of general industrial solid waste. The energy and electricity consumption per unit of the regional gross domestic product primarily reflect the extent of resource consumption during urban economic development [27]. On the other hand, water conservation and the comprehensive utilization of general industrial solid waste embody the level of efficient resource utilization.
- (c) Environmental protection. Environmental protection primarily encompasses 6 indicators: the intensity of general industrial solid waste generation, the total wastewater treatment, the harmless treatment of household garbage, the green coverage in built-up areas, the road cleaning and maintenance area, and the financial expenditure on energy conservation and environmental protection. The intensity of general industrial solid waste generation is utilized to inversely reflect the extent of environmental degradation caused by industrial production. Meanwhile, the total wastewater treatment, harmless treatment of household garbage, green coverage in built-up areas, road cleaning and maintenance area, and financial expenditure on energy conservation and environmental protection reflect the level of investment in environmental governance.
- (d) Well-being of the people. It includes the average wage of on-the-job staff, the year-end number of employed persons in the entire society, the number of individuals covered by the 3 major social insurances, the number of public toilets per ten thousand people,

and the number of sanitation vehicles per ten thousand people. Among these, the average wage of on-the-job staff and the year-end number of employed persons in the entire society reflect people's income and employment situations. In addition, the number of individuals covered by the 3 major social insurances signifies the level of social welfare. The number of public toilets per ten thousand people and the number of sanitation vehicles per ten thousand people reflect the state of completeness of social infrastructure.

Table 1. Evaluation Framework for the Green Economy.

Primary Indicators	Secondary Indicators	References
Economic growth	Per capita regional gross domestic product	Tasri (2016) [28], Helberger (2022) [29]
	Economic density	
	Proportion of industrial output	
	Proportion of tertiary industry output	
Resource conservation	R&D expenditure	Worthington (2005) [30], Vargas (2020) [31]
	Unit energy consumption of regional gross domestic product	
	Unit electricity consumption of regional gross domestic product	
	Water conservation	
	Comprehensive utilization of general industrial solid waste	
Environmental protection	General industrial solid waste production intensity	Bartlett (2010) [32], Salmon (2022) [33]
	Total sewage treatment	
	Harmless treatment of household garbage	
	Green coverage area in built-up areas	
	Road cleaning and maintenance area	
Well-being of the people	Financial expenditure on energy conservation and environmental protection	Marudhamuthu (2011) [34], Rebeck (2014) [35]
	Average wage of employees in post	
	Total year-end employment in all sectors	
	Number of people participating in the three insurances	
	Number of public toilets per ten thousand people	
	Number of sanitation vehicles per ten thousand people	

(2) Explanatory variables

The explanatory variable in this paper is the environmental regulation (ER). Scholars have proposed various methods for estimating the environmental regulations [35]. By considering the strengths and weaknesses of different approaches, we opt to measure the environmental regulations using pollution control costs. We developed an Environmental Regulation Assessment Index to assess the level of environmental regulations in China over the years. One advantage of utilizing this index is its ability to reflect the actual investment China has made in industrial environmental governance [36]. Additionally, this index mitigates errors in assessing the level of the environmental regulations due to differing industrial structures across regions. The specific method is outlined as follows:

$$COST_t = \frac{Amounts_t}{Add_t} \quad (1)$$

In Equation (1), *COST* represents the pollution control costs per unit industrial output value in China for year *t*. *Amounts* stands for the completed industrial pollution control investment. *Add* denotes the industrial value added. In this formula, a higher value of *COST* indicates stronger environmental regulations. Conversely, a lower value suggests weaker environmental regulations.

(3) Intermediate variable

The mediating variable in this paper is green technological innovation (GTI). The majority of researchers utilize the quantity of patent applications in the different regions as a significant indicator of local technological innovation [37,38]. Therefore, we employ the number of green patent technology applications in China across various years to measure

green technological innovation. The relevant data are sourced from patent application reports released by provincial science and technology departments.

In addition, we have defined the output time of green technology innovations. In order to ensure the availability of the research data and the reliability of the research conclusions, we choose the enterprise green technology innovation data from 2004 to 2023. This output time is also chosen to be consistent with the time of the data for the other variables.

(4) Control variables

In this paper, the authors aimed to minimize endogeneity issues by controlling for other variables that may have significant impacts. These control variables are as follows.

- (a) Investment in green technological innovation (IGT). We utilized the funds allocated by businesses or governments for research and innovation in green technologies as a proxy for this indicator. The level of investment is quantified by examining the financial resources directed towards green technology research and development by enterprises or governments [39].
- (b) Fixed-asset investment (FAI). Total fixed-asset investment refers to all funds spent within a specific period for the acquisition, construction, or renovation of fixed assets. This metric could reflect the overall scale of investment in fixed assets within a country, region, or industry [40]. Therefore, we use total fixed-asset investment to represent this indicator.
- (c) Optimization of industrial structure (OIS). The share of industrial value added signifies the proportion of an industry within the overall national economy [41]. By monitoring the value-added shares of different industries, one could evaluate the optimization of industrial structure. We place emphasis on the share of high-value-added industries. Therefore, we employ the share of the industrial value added as a representation of this indicator.
- (d) Green technological innovation talent (GTI). We employ the quantity of professionals engaged in the field of green technology to symbolize this indicator [42]. The amount of talent in green technology encompasses professionals in some areas. It includes green energy, environmental science, and sustainable development.

4.2. Empirical Model Establishment

4.2.1. Construction of the Baseline Regression Model

The reasons for using the regression model in this paper are as follows: (1) In the field of green economy research, the regression model shows a wider application and mature research basis. Previous experience and research results could provide strong support and verification. It could increase the reliability and credibility of the conclusions of this paper. (2) The regression model shows better adaptability to the data structure and characteristics of the green economy and the environmental regulations. It could be more consistent with the distribution of data and the relationship between variables. At the same time, it is also able to capture key information and trends more accurately. (3) The regression model shows unique advantages in dealing with specific types of variables. We could use the model to better analyze the complex interaction between the main variables in this paper.

This paper aims to comprehensively explore the intrinsic relationship among the environmental regulations, green technological innovation, and the green economy. Based on the research conclusions of relevant scholars, the following regression model has been developed:

$$\ln GE_{it} = \alpha_0 + \alpha_1 \ln ER_{it} + \alpha_2 \ln GTI_{it} + \varepsilon_{it} \quad (2)$$

In model (2), $\ln GE$ represents the level of the green economy. $\ln ER$ represents the status of the environmental regulations. $\ln GTI$ represents the level of green technological innovation. and ε_{it} denotes the error term. In order to prevent potential biases resulting from omitted variables during estimation, this paper has constructed a new regression

model (3) based on model (2). Relevant control variables that may influence the green economy have also been included in the regression model (3). Model (3) is as follows:

$$\text{LnGE}_{it} = \alpha_0 + \alpha_1 \text{LnER}_{it} + \alpha_2 \text{LnGTI}_{it} + \beta_i \text{LnN}_{it} + \varepsilon_{it} \quad (3)$$

In model (3), N_{it} signifies the control variables influencing green economic development. This paper aims to delve even deeper into the impact process of the interactive dynamics among the 3 variables. Hence, we elaborate by constructing regression model (4). Through the utilization of model (4), we could unveil the effects of the interaction term between the environmental regulations and green technological innovation on the green economy. The format of model (3) is presented below:

$$\text{LnGE}_{it} = \alpha_0 + \alpha_1 \text{LnGTI}_{it} + \alpha_2 (\text{LnGTI}_{it} \times \text{LnER}_{it}) + \beta_i \text{LnN}_{it} + \varepsilon_{it} \quad (4)$$

4.2.2. Construction of the Panel Threshold Regression Model

Given the evolving landscape of the environmental regulation, the impact of green technological innovation on the green economy may exhibit nonlinear variations [43]. Consequently, we proceed to formulate panel threshold regression model (5). Through the model, insights into the environmental regulatory threshold effect of green technological innovation on the green economy could be unveiled. The structure of model (5) is as follows:

$$\text{LnGE}_{it} = \alpha_0 + \alpha_1 \text{Lngi}_{it} \times I(\text{Lndf}_{it} \leq c) + \alpha_2 \text{Lngi}_{it} \times I(\text{Lndf}_{it} > c) + \beta_i \text{LnN}_{it} + \varepsilon_{it} \quad (5)$$

In model (5), $I(\cdot)$ represents the indicator function, with c denoting the threshold value. In this research model, the central threshold value pertains to the level of environmental regulation.

4.3. Data

The paper primarily focuses on the relevant data from the period spanning 2004 to 2023. During this time, China has witnessed rapid advancements in environmental regulations, the green economy, and green technology. These changes are distinct and marked by notable characteristics.

The indicators for the green economy are sourced from the China Statistical Yearbook. Metrics for green technological innovation are derived from the Ministry of Science and Technology of China. The environmental regulation indicators are obtained from the China Environmental Statistical Yearbook and China Energy Statistical Yearbook. Moreover, regarding controlling variables, data related to investment in green technological innovation are released by the relevant departments. Data concerning fixed-asset investment mainly originate from the China Statistical Yearbook. Information on the optimization of industrial structure is predominantly sourced from the Ministry of Commerce in China. In addition, data on green technological innovation talent are primarily sourced from the National Bureau of Statistics of China. A descriptive statistical analysis of variables is presented in Table 2, showcasing the data characteristics of all variables in this paper.

Table 2. Descriptive Statistical Analysis of Variables.

Categories of Variables	Variables	Min.	Max.	Mean	Standard Deviation
Explained variable	GE	0.5892	5.3917	2.8942	0.8109
Explanatory variables	ER	1.0745	2.7914	2.0883	0.8046
Intermediate variable	GTI	0.6932	5.4172	2.8309	0.8812
	IGT	2.3781	4.9903	3.4811	0.9739
Control variables	FAI	0.4954	3.2071	1.4872	0.7823
	OIS	2.6639	5.8722	3.0143	0.8903
	GTT	1.3842	7.0426	3.5592	0.7293

5. Results

5.1. Benchmark Regression Analysis

The regression results on the impact of the environmental regulations on the green economy, as shown in Table 3, reveal meaningful insights. In Model (1), the coefficient associated with the environmental regulations is positive and significant at the 10% level, indicating a notably influential role in driving the advancement of the green economy. Subsequently, Model (2) incorporates four additional control variables—IGT, FAI, OIS, and GTT—upon the Model (1) framework. Notably, in Model (2), the environmental regulations retain a positive coefficient which remains statistically significant at the 1% level. Thus, it provides robust validation for hypothesis H1 in this paper.

Table 3. Regression results of the impact of the environmental regulations on the green economy.

Variables	<i>lnGE</i> (1)	<i>lnGE</i> (2)	<i>lnGTI</i> (3)	<i>lnGE</i> (4)
<i>LnER</i>	2.943 * (0.052)	2.003 *** (0.049)	6.317 * (0.072)	1.448 ** (0.031)
<i>lnGTI</i>				0.025 * (0.019)
<i>lnIGT</i>		0.388 *** (0.019)	0.662 ** (0.184)	0.452 * (0.083)
<i>lnFAI</i>		0.014 (0.029)	0.361 (0.199)	0.074 (0.057)
<i>lnOIS</i>		0.932 ** (0.014)	0.274 * (0.063)	1.883 * (0.059)
<i>lnGTT</i>		1.037 * (0.031)	7.039 *** (1.983)	4.022 * (0.085)
C	6.319 ** (0.092)	5.188 * (0.702)	21.407 *** (10.188)	22.558 * (7.094)
Time	Control	Control	Control	Control
Individuals	Control	Control	Control	Control
N	3103	3103	3103	3103
R ²	0.4923	0.3806	0.5172	0.5883

Note: ***, **, and * denote significance at the 1%, 5%, and 10% confidence levels, respectively.

Furthermore, the coefficient of *lnFAI* appears to be statistically insignificant. It suggests that the investments in fixed assets do not significantly impact the green economy. However, the positive and significant coefficient of *lnIGT* implies that expanding investments in green technology innovation could facilitate technological innovation. It would consequently uplift the local green economic levels.

Moreover, the coefficient of *lnOIS* is positive and significant. It suggests that the optimizing regional industrial structure contributes to the sustainability of the green economy. Lastly, the coefficient of *lnGTT* is also positive and notably significant. It shows that the increase in talent specialized in green technology innovation could propel the green economic levels.

5.2. Mediation Analysis

The paper validates the impact process of the environmental regulations on the green economy. Furthermore, we would further investigate the mediating role of corporate green technological innovation in this context. The results of the mediation effect model are presented in Table 3. It is evident that the coefficient reflecting the impact of the environmental regulations on green technological innovation is statistically significant at the 5% level and positive. Concerning the coefficients of the environmental regulations on the green economy in Model (4), they are smaller than those in Model (2). It indicates a significant mediating effect of green technological innovation in the impact of the environmental regulations on the green economy. Therefore, this regression outcome once again confirms hypothesis H1.

5.3. Analysis of Nonlinear Threshold Effects

This paper further integrates the analysis of nonlinear threshold effects to investigate the impact of the environmental regulations on the green economy. Employing a panel regression model, the focus lies on the environmental regulations and firm-level green technological innovation. The inquiry delves into whether the nonlinear relationship between the environmental regulations and the green economy varies with changes in the environmental regulations and green technological innovation at the firm level. Firstly, a threshold existence test is conducted on the panel model, with the results presented in Table 4. The empirical data reveal the presence of a significant single threshold for the advancement of the environmental regulations and firm-level green technological innovation on the green economy. However, no evidence suggests the existence of dual- or triple-threshold effects, thus enabling the construction of a single-threshold regression model in this paper.

Table 4. Analysis results of the threshold existence test.

Threshold Variable	Quantity of Thresholds	F Value	p Value	BS Frequency	Threshold Value	1%	5%	10%
<i>lnER</i>	A singular threshold	21.835	0.0001	300	−2.7842	11.278	15.602	16.297
<i>lnGTI</i>	A singular threshold	33.092	0.0002	300	3.6988	26.940	27.883	36.981

The results of the single-threshold regression are depicted in Table 5. The data presented in the table reveal that when both environmental regulations and firm-level green technological innovation are below the threshold values, the regression coefficient of the environmental regulations on the green economy is significantly positive at the 10% level. It suggests the presence of clear spillover effects from the environmental regulations. Furthermore, as the environmental regulations and firm-level green technological innovation increase and surpass the threshold values, the impact coefficient of the environmental regulations on the green economy also becomes significantly positive at the 1% level, surpassing the previous coefficient. It indicates a substantial driving force of the environmental regulations on the green economy. Simultaneously, firm-level green technological innovation plays a positive mediating role and exhibits a nonlinear characteristic of increasing marginal effects. Thus, hypothesis H2 of this paper is validated.

Table 5. Results of univariate threshold regression analysis.

Variables	Coefficients	Variables	Coefficients
Threshold value	−2.7842	Threshold value	3.6988
$\ln ER \times I (q \leq -2.7842)$	1.7832 *	$\ln GTI \times I (q \leq 3.6988)$	1.3671 *
$\ln ER \times I (q > -2.7842)$	1.0493 *	$\ln GTU \times I (q > 3.6988)$	1.7442 ***
Control variables	Control	Control variables	Control
N	3103	N	3103
R ²	0.4988	R ²	0.4172

Note: *** and * denote significance at the 1% and 10% confidence levels, respectively.

5.4. Spatial Spillover Effect Analysis

This paper aims to verify the existence of spatial autocorrelation. We divide China into three regions. They are the Eastern region, the Western region, and the Central region. They are divided according to the following: (1) There are significant differences in geographical location and economic development level. They show obvious differences in geographical location. Moreover, there is a certain gradient in the level of economic development. This division could better reflect the geographical characteristics and economic conditions of different regions. At the same time, it is conducive to regional comparison and analysis. (2) Data availability and research needs. In the analysis of spatial spillover effect, it is necessary to use relevant economic data and geographic information. Dividing China into

three larger regions makes it easier to obtain and organize data. At the same time, it is also conducive to cross-regional comparison and research.

By incorporating a geographic distance weighting matrix, we measure the Moran's I index of the environmental regulation and the green economy across different regions. The test results are presented in Table 6. From 2014 to 2023, there was a significant positive spatial correlation between the environmental regulation and the green economy. It implies a spatially correlated distribution of the environmental regulation and the green economy. During the examination using the SLM model, only the LR effect test passed the fixed-time effect test. Therefore, we opt for the fixed-time effect model. The Hausman test results suggest rejecting the null hypothesis of this paper and selecting a fixed effect. Moreover, the LR tests all showed significant results and rejected the null hypothesis. Consequently, the SDM model could not be simplified into SLM or SEM models. The paper should determine a spatial SDM model with fixed-time effects. Furthermore, this paper seeks to accurately assess the spatial spillover effects of each variable on the green economy. Thus, we estimate various effects within the SDM model of the environmental regulation. The direct effects illustrate the impact of the environmental regulation on the local green economic development. However, the indirect effects demonstrate the influence of neighboring regions' environmental regulation on local the green economy. This approach helps illuminate the spillover effects in space.

Table 6. Moran'I index of SDL and EGI.

Year	Moran'I Index of SDL	Year	Moran'I Index of EGI
2014	0.092 **	2014	0.023 ***
2015	0.104 *	2015	0.024 *
2016	0.091 **	2016	0.028 ***
2017	0.103 ***	2017	0.020 **
2018	0.095 *	2018	0.017 *
2019	0.092 **	2019	0.029 **
2020	0.099 **	2020	0.027 **
2021	0.092 *	2021	0.032 **
2022	0.096 *	2022	0.039 **
2023	0.095 ***	2023	0.038 *

Note: ***, **, and * denote significance at the 1%, 5%, and 10% confidence levels, respectively.

The regression results of the dynamic SDM model with the fixed-time effects and the spatial effects of explanatory variables are displayed in Table 7. The data in the table reveal that the spatial correlation coefficient of the environmental regulation is significantly positive at the 10% level. It signifies a notable interplay among regions in the environmental regulation, indicating a significant spatial effect. The green economy in a given area exhibits a positive correlation with the development of the green economy in neighboring areas. It suggests a correlated development of the green economies across regions. The regression coefficient of the environmental regulation is significantly positive at the 10% level. It indicates that the environmental regulation could enhance the level of the green economy. Moreover, the regression coefficient for green technological innovation is significantly positive at the 5% level. It implies that higher levels of innovation in green technologies by enterprises lead to an increased level of development in the green economy.

The aforementioned regression analysis fails to comprehensively reflect the impact process of explanatory variables on the dependent variable [44]. Consequently, this paper delves deeper by conducting a partial differentiation of the regression coefficients. Thus, we obtain the direct and indirect effects of each explanatory variable. Through these effect analyses, a more precise understanding of the interrelations among variables could be achieved. The specific outcomes are presented in the last two columns of Table 7. The direct effect coefficient of the central variable, environmental regulation, is significantly positive at the 10% level in the model. Simultaneously, the indirect effect coefficient of the environmental regulation is significant at the 10% level and positive. It indicates that

while environmental regulation enhances the development of the local green economy, it is disadvantageous to the development of the green economies in neighboring areas. This is primarily due to the fact that the advancement of local environmental regulation attracts an inflow of talent, capital, information, and technology from surrounding regions. It results in a shortage of resources required for the environmental regulation in neighboring areas. Furthermore, the direct effect coefficient of green technological innovation is significantly positive at the 10% level. However, the indirect effect coefficient is not significant. It suggests that green technological innovation could enhance the development of the local green economy but does not influence the green economies in neighboring areas. Therefore, green technological innovation exhibits a spatial spillover effect on the green economy. Additionally, it is assumed that Hypothesis 3 has been effectively validated.

Table 7. Results of spatial model regression and spatial effect decomposition.

Variables	Main	Wx	Spatial	Variance	Direct	Indirect
<i>lnER</i>	0.372 * (0.052)	−0.993 ** (0.187)			0.572 * (0.048)	−3.669 * (0.062)
<i>lnGTI</i>	0.038 ** (0.022)	−0.052 * (0.042)			0.049 * (0.023)	0.051 (0.039)
ρ			0.637 * (0.021)			
σ^2				0.427 *** (0.019)		
Control variables				Control		
Obs	3177	3177	3177	3177	3177	3177
N	290	290	290	290	290	290
R ²	0.418	0.422	0.396	0.372	0.366	0.359

Note: ***, **, and * denote significance at the 1%, 5%, and 10% confidence levels, respectively.

5.5. Analysis of Regional Heterogeneity

A spatial spillover effect analysis is conducted on the data. The results reveals a robust spatial correlation among the environmental regulations, green technological innovation, and the green economy. With China's vast territorial expanse, significant disparities in the environmental regulations and the progress of the green economy exist across various regions. In light of this, our aim is to delve deeper into the relationship status between the environmental regulations and the green economy in different regions. Consequently, this paper proceeds to undertake further analysis of the regional heterogeneity [45].

Drawing from the research conducted by relevant scholars, this paper categorizes the regions into Eastern, Central, and Western regions. Building upon pertinent survey data, the heterogeneous relationships among the environmental regulations, green technological innovation, and the green economy in different regions are scrutinized. The estimation results of the regional heterogeneity are presented in Table 8. The data reveal that there are certain disparities in the relationships among them across different regions of China: (1) Across the three regions, the impact of the environmental regulations on the green economy is consistently positive. Concerning the degree of this impact, the magnitude follows a descending order from the Eastern region to the Central region and then to the Western region. This pattern mainly stems from the stringent environmental regulations in the Eastern region. Moreover, even minor variations could exert a substantial influence on the development of the green economy in that area. (2) The influence of green technological innovation on the green economy is positively significant in all three regions. The extent of this influence ranks highest in the Western region, followed by the Central region and then the Eastern region. This trend arises primarily from the weaker capacity for green technological innovation in the Western region. Nevertheless, an increase in green technological innovation within enterprises in this region could significantly stimulate sustainable development of the local green economy.

Table 8. Analysis of Regional Heterogeneity Estimation.

Variables	Eastern Region	Central Region	Western Region
<i>lnER</i>	1.729 ** (0.223)	1.592 ** (0.205)	1.442 ** (0.239)
<i>lnGTI</i>	1.108 * (0.036)	1.937 ** (0.148)	2.088 *** (0.092)
<i>lnIGT</i>	0.441 * (0.029)	0.372 * (0.161)	0.204 * (0.056)
<i>lnFAI</i>	1.174 *** (0.054)	0.299 * (0.053)	0.188 *** (0.062)
<i>lnOIS</i>	0.382 ** (0.299)	1.084 *** (0.225)	0.553 * (0.027)
<i>lnGTT</i>	0.719 * (0.224)	0.037 * (0.094)	1.593 * (0.025)
C	4.309 ** (1.743)	5.682 *** (2.841)	9.443 *** (2.714)
N	342	342	342
R ²	0.629	0.647	0.661

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

5.6. Endogeneity Test

Instrumental variable analysis is the main method to solve endogenous problems [46]. In order to solve the possible endogeneity problem of the model in this paper, we conducted an endogeneity test on it. The endogeneity test results of this paper are shown in Table 9. The test results show that even considering the endogenous factors, the impact of the environmental regulation on the green economy is still positive. At the same time, it is significant at the 5% level. Moreover, in the first-stage regression, the *f* statistic is greater than 30. It indicates that there are no weak instrumental variables in this paper. The *p*-value of the Sargan test is greater than 0.18. It shows that the instrumental variables meet the exogenous requirements. The tests show that the model chosen in this paper does not have endogeneity problems. Therefore, the results of this paper are credible.

Table 9. Results of 2-stage least square method for instrumental variables.

	First	Second
Variables	ER	GE
ER		1045 ** (255.19)
Con_	Yes	Yes
z_1	0.003 ** (0.0002)	
z_2	0.004 ** (0.0002)	
z_3	0.0007 ** (0.0003)	
F statistic	31.36	
Sargan test		0.19
R ²	0.735	0.702

Note: ** represents the significance level of 5%.

5.7. Robustness Test

To strengthen the accuracy and reliability of the paper's conclusions, further robustness tests are conducted on the empirical model [47]. Prior to the robustness tests, a systematic data preprocessing is performed by the authors. To mitigate the influence of outliers, the data underwent truncation, a step that is excluded during the robustness test. The test results are shown in Table 10. The results of the robustness tests indicate that the coefficients of key variables remain consistent in terms of impact direction and significance

when compared to earlier studies. This finding underscores the reliability and robustness of both the model specifications and the corresponding regression results in this paper.

Table 10. Results of robustness tests.

Variables	(1)	(2)	(3)
<i>lnER</i>	1.782 ** (0.096)	1.882 *** (0.107)	1.905 * (0.114)
<i>lnGTI</i>	0.43 ** (0.010)	0.051 * (0.011)	0.084 ** (0.015)
<i>lnIGT</i>	0.217 ** (0.022)	0.395 * (0.035)	0.573 ** (0.044)
<i>lnFAI</i>	0.083 * (0.014)	0.115 ** (0.029)	0.186 * (0.072)
<i>lnOIS</i>	2.653 ** (0.062)	3.784 ** (0.061)	3.672 * (0.055)
<i>lnGTT</i>	1.284 ** (0.391)	2.554 ** (0.592)	2.648 * (0.378)
C	6.271 ** (1.338)	7.242 *** (1.579)	6.392 * (1.564)
N	481	481	481
R ²	0.492	0.507	0.558

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

6. Conclusions, Implications and Research Limitations

6.1. Conclusions

- (1) The environmental regulations could directly enhance the green economy. Furthermore, this impact process is not the result of a single factor [48]. Through robustness testing, the conclusions of this paper remain reliable. It implies that, in the process of developing a green economy, a region must fully consider its environmental regulatory framework. Simultaneously, the region must further comprehensively examine the combined effects of various factors.
- (2) Regarding the mediating effects, the environmental regulations could indirectly enhance green economic development through the mediating variable of green technological innovation. In other words, in the process where the environmental regulations influence the green economy, the behavior of green technological innovation also plays a crucial role. Particularly, against the backdrop of continuously improving green technological innovation capabilities, the development of regional green economies would progress at a faster pace.
- (3) Significant spatial correlations exist between the environmental regulations and the green economies across different regions in China [49]. It implies that regional development needs to consider both its own green economic advancement and the environmental regulatory requirements of the region. Simultaneously, it should also take into account the circumstances of surrounding areas. Consequently, the regional green economy management policies should adapt to changes in the environmental regulations and the green economic development in neighboring regions.
- (4) In the Eastern, Western, and Central regions of China, there are notable differences in the relationships among the environmental regulations, enterprise green technological innovation, and the green economies across distinct regions. The changing environmental regulations show the greatest impact on the development of green economies in the Eastern region. Conversely, variations in green technological innovation show the most significant influence on the green economies in the Western region. Therefore, the emphasis of green economy development management varies across different regions.

First, in the Eastern region, the regulatory authorities should improve and strictly regulate the environment. Government departments should strengthen the supervision and punish-

ment of enterprises with high pollution and high energy consumption. They should also increase capital investment in green technology innovation. At the same time, the government should support enterprises in carrying out cutting-edge green technology research.

Secondly, in the Western region, the government should combine the advantages of local resources and formulate targeted environmental regulation policies. At the same time, enterprises should strengthen the training and education of green technology innovation. Furthermore, they should improve the innovation ability of scientific researchers. The government should also actively introduce advanced green technology and management experience from the Eastern region and give preferential policies. It would also attract green technology innovators to take root in the Western region.

Finally, in the Central region, the government should optimize the implementation mechanism of environmental regulation policies to ensure the effective implementation of policies. At the same time, the administrative departments should encourage universities and scientific research institutions to cooperate with enterprises to jointly carry out green technology innovation projects. Enterprises should promote the green transformation and upgrading of traditional industries. It should also use green technologies to improve production efficiency and resource utilization.

6.2. Implications

The implications of this paper could be summarized by combining the research conclusions. The corresponding relationship between the two aspects is shown in Figure 2. Based on the four conclusions, we put forward the three implications.

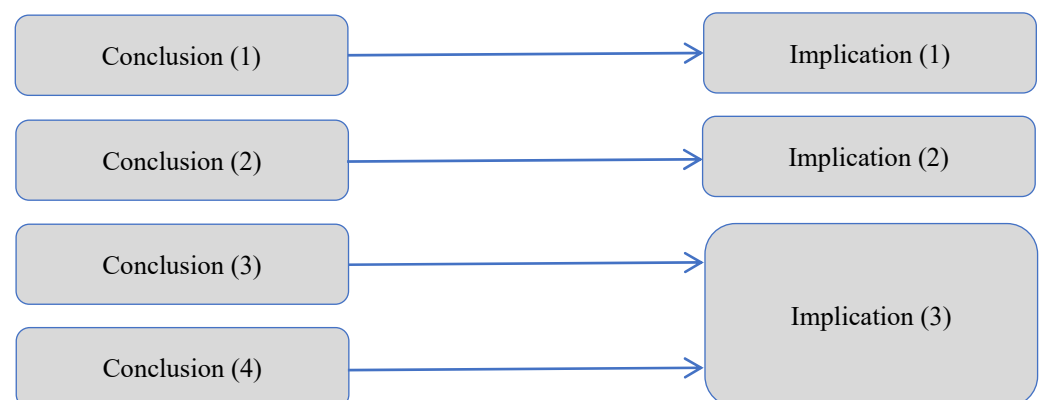


Figure 2. The relationship between the conclusions and the implications.

(1) Relevant enterprises should leverage the environmental regulations to advance their green economies. Initially, companies should adhere to environmental laws to ensure that their production activities comply with regulatory requirements. It is imperative for businesses to establish robust environmental management systems and formulate environmental policies and objectives. They also should conduct environmental risk assessments. Concurrently, enterprises should invest in green technology innovations, incorporate renewable energy sources, and adopt energy-saving and emission-reducing technologies. By doing so, companies could enhance resource utilization efficiency and decrease carbon emissions.

Furthermore, enterprises could drive a green supply chain by collaborating with suppliers to steer the entire supply chain towards eco-friendly practices [50]. Through partnerships with suppliers and advocating for environmentally friendly production methods, both entities could collectively propel the development of green economies. Additionally, it is crucial for companies to engage in environmental advocacy and education. By raising awareness among employees and consumers about environmental protection, companies could promote green consumption and production methods, fostering an environmentally conscious atmosphere.

Lastly, companies could engage in carbon markets and trading to stimulate carbon emission reductions through mechanisms such as carbon emission rights trading, thereby advancing the development of green economies. Moreover, collaboration with government is also vital. Governments and businesses could collaboratively formulate and implement environmental policies and regulations, jointly propelling the development of green economies. By implementing these key strategies, companies could fully harness the guiding role of the environmental regulations, promote the healthy development of green economies, and achieve a win-win situation of economic growth and environmental protection.

(2) Relevant enterprises must drive the development of the green economies through innovation in green technologies. Primarily, companies could invest in developing and adopting green technologies such as renewable energy, energy efficiency enhancement technologies, and clean production processes. By incorporating these technologies, businesses could reduce reliance on traditional energy sources, lower carbon emissions and environmental impact, thereby achieving sustainable development. Moreover, the application of these technologies could enhance a company's competitiveness, meeting the escalating demand of consumers for eco-friendly products and services.

Secondly, businesses could propel green economies through innovation in digitalization and intelligent technologies; for instance, leveraging big data analytics and artificial intelligence to optimize production processes, reduce energy consumption and waste emissions; introducing Internet of Things technologies to enable intelligent energy management. It also could enhance resource utilization efficiency. The application of these technologies not only aids in reducing operational costs for enterprises but also supports improvements in production efficiency and environmental friendliness.

Lastly, companies could collaborate with research institutions, industry associations, and other entities to jointly undertake green technology innovation projects. Through interdisciplinary collaboration, enterprises could access more resources and specialized knowledge, accelerating the application of green technologies. Simultaneously, establishing open innovation platforms to facilitate exchanges and collaborations across diverse fields could promote the application of green technologies on a broader scale. The integrated application of these methods could assist companies in achieving greater progress along the path of advancing green economies.

(3) Balancing the levels of green economy development across different regions based on environmental regulatory characteristics is essential. Initially, relevant governments should tailor specific policies and regulations according to the environmental regulatory features of each region. By addressing the unique environmental challenges and resource endowments of different areas, governments need to formulate corresponding environmental protection policies and industry standards to foster the advancement of the green economies. For instance, in regions abundant in resources yet constrained by limited environmental capacity, governments could enforce stringent emission standards and resource management measures to guide enterprises towards transitioning to clean production and circular economy practices.

Secondly, governments could establish cross-regional cooperation mechanisms to promote the coordination and harmonization of environmental regulations [51]. By sharing experiences, technologies, and resources among different regions, collaborative efforts could tackle transregional environmental challenges, driving green technology innovation. Through cross-regional cooperation, optimal resource allocation could be achieved, enhancing the environmental regulations and promoting the balanced development of green economies.

Lastly, relevant departments should strengthen supervision and evaluation mechanisms to ensure the effective evaluation of the environmental regulations [52]. Governments should establish robust regulatory systems, enhance monitoring and inspection of the environmental regulatory compliance and take necessary measures to address them. Additionally, governments should create scientific assessment criteria systems to quantitatively evaluate the implementation effects of the environmental regulations. It could provide a scientific basis and policy recommendations for the development of the green economies

in different regions. By comprehensively applying the above measures, the balance of the green economy development levels across various regions could be promoted, leading to a win-win scenario of environmental protection and economic growth.

6.3. Research Limitations and Future Research Directions

Research limitations. Due to constraints in the length of the paper and the authors' time and resources, this paper still exhibits the following research limitations: (1) The research sample in this paper still needs to be expanded. The data collected in this paper amount to 3103 samples, all originating from China. However, the impact of the environmental regulations on green economic development is a global phenomenon. Therefore, the research sample remains relatively limited. (2) The research theme requires enhancements. This paper solely delves into the impact of the environmental regulations on the green economy without investigating how the environmental regulations affect aspects such as enhancing corporate performance, controlling corporate costs, and the efficacy of governmental policies. (3) The mediation variables need to be diversified. This paper only considers green technological innovation as a mediation variable, omitting the exploration of other variables to serve as mediation factors.

Future research directions. Based on the existing limitations in this paper, we outline the following future research directions: (1) We intend to broaden the scope of the surveyed samples. In forthcoming research endeavors, we aim to expand the range of relevant surveyed data. Particularly, we could incorporate data from emerging developing countries or data from developed nations. Research findings derived from survey data across different regions are likely to exhibit significant variations. Hence, our future investigations may yield diverse conclusions from other regions. (2) We are committed to refining the research themes. Future research initiatives could delve deeper into the impact process of environmental regulations on corporate performance, corporate costs, governmental policy efficacy, among other aspects. By doing so, we could effectively enrich the content of related research themes. (3) We plan to introduce additional mediation variables. To bolster the comprehensiveness of our inquiries, our future studies may introduce new mediation variables. Variables that could be included encompass governmental policies, socio-economic environments, and the atmosphere of social innovation.

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